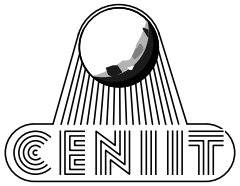
Knut och Alice Wallenbergs Stiftelse
Wallenberg Centre for Quantum Technologies



QUANTERA
ERA-NET Cofund in Quantum Technologies

Minimizing detection losses from time-bin quantum cryptography systems with few-mode fibre technology

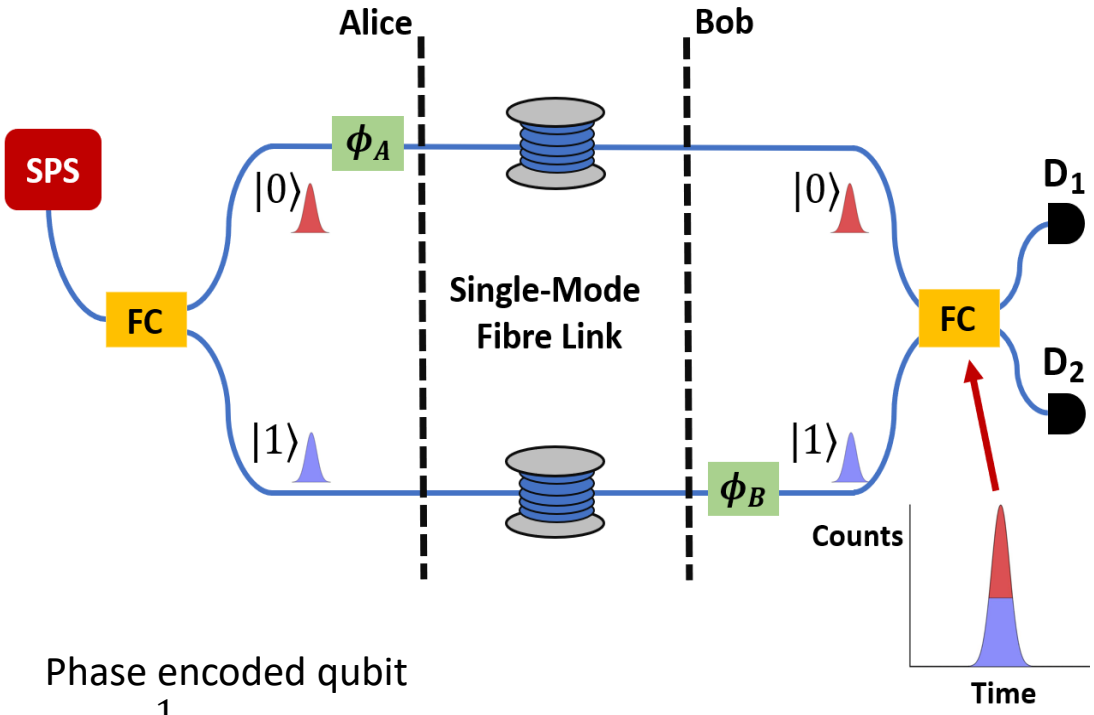
Qcrypt 2021

Alvaro Alarcón, Joakim Argillander, Gustavo Lima and Guilherme B. Xavier
Electrical Engineering Department
Linköping University

LINKÖPING UNIVERSITY

Phase and time-bin QKD

Phase encoding



Output probabilities proportional to $\boldsymbol{cos^2(\phi_A - \phi_B)}$ and $\boldsymbol{sin^2(\phi_A - \phi_B)}$

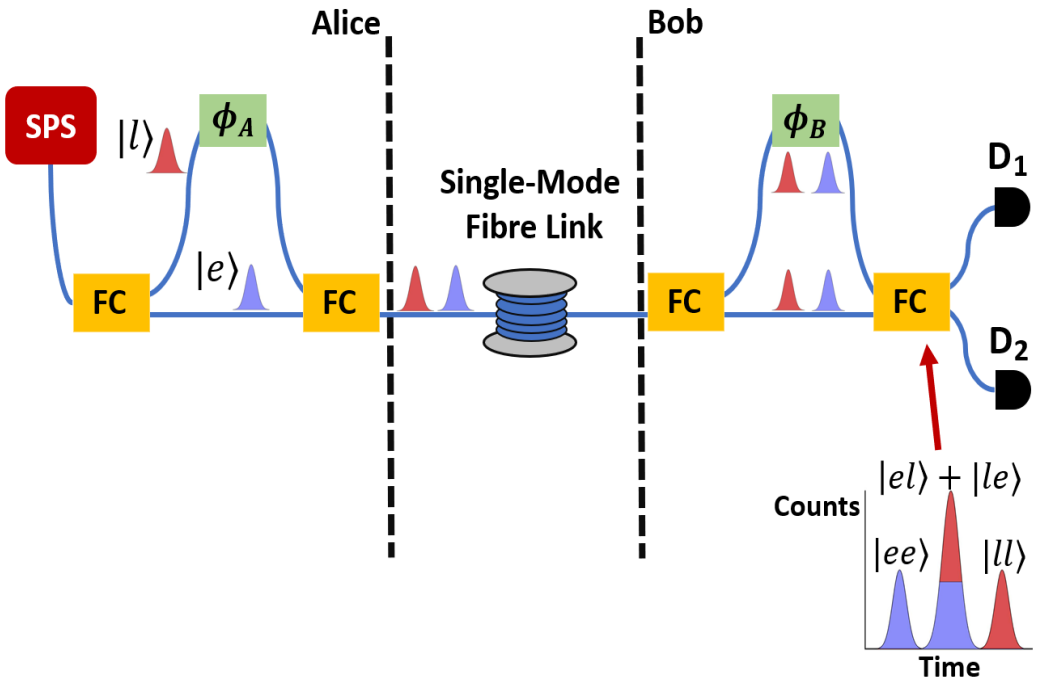
Phase encoded qubit

$$|\psi\rangle = \frac{1}{\sqrt{2}}\left(|0\rangle + e^{i\phi_A}|1\rangle\right)$$

The drawback is that long interferometers are needed

Phase and time-bin QKD

Time-bin encoding



Time-bin encoded qubit

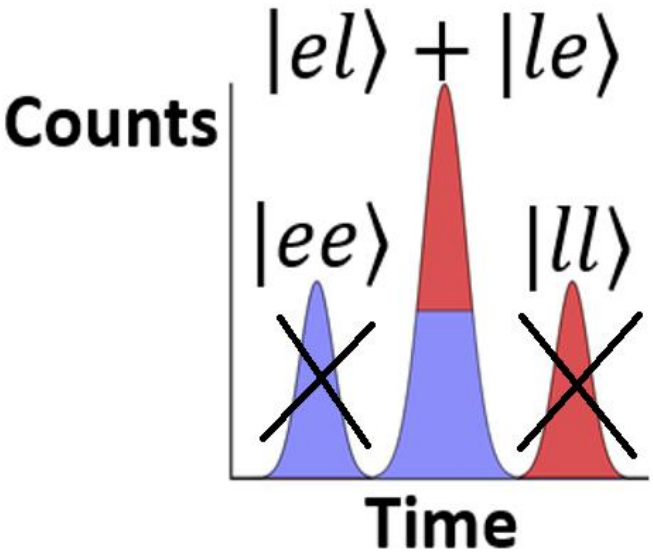
$$|\psi\rangle = \frac{1}{\sqrt{2}}\left(|e\rangle + e^{i\phi_A}|l\rangle\right)$$

*Now only one fiber is needed

*Easier to actively stabilize

Phase and time-bin QKD

Time-bin encoding

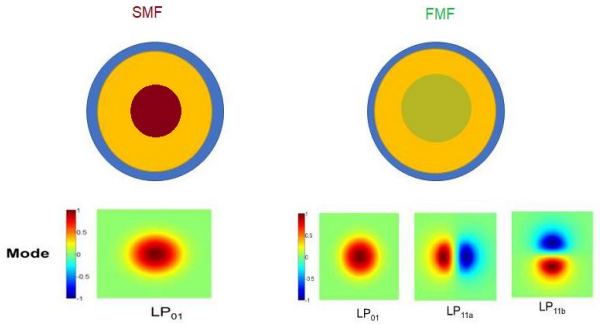


The trade-off of using Time-bin is that we must discard information (post-selection). In the case of 2 dimensions, 50% of the information is lost

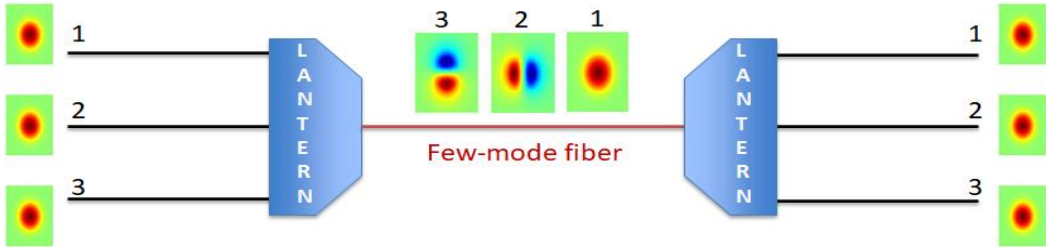
The post-selection loss gets even more pronounced at high-dimensions. It scales as ***(d-1)/d***

A. Alarcon, J. Argillander, G. Lima and G. B. Xavier, *submitted* (2021).

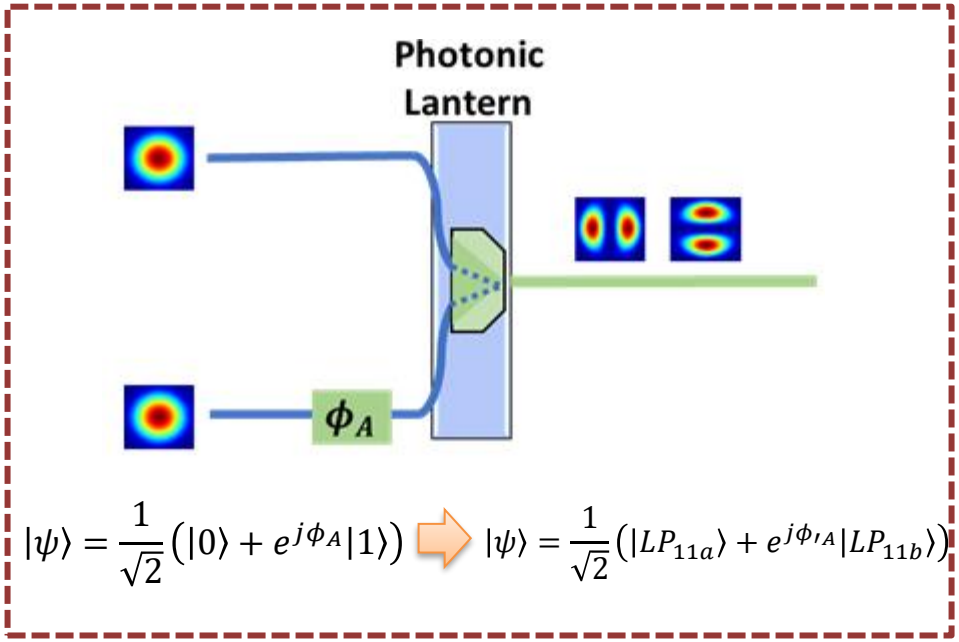
Spatial Mode-Division Multiplexing



Linearly polarized (LP) modes. LP_{01} , LP_{11a} , LP_{11b} are orthogonal modes to each other.

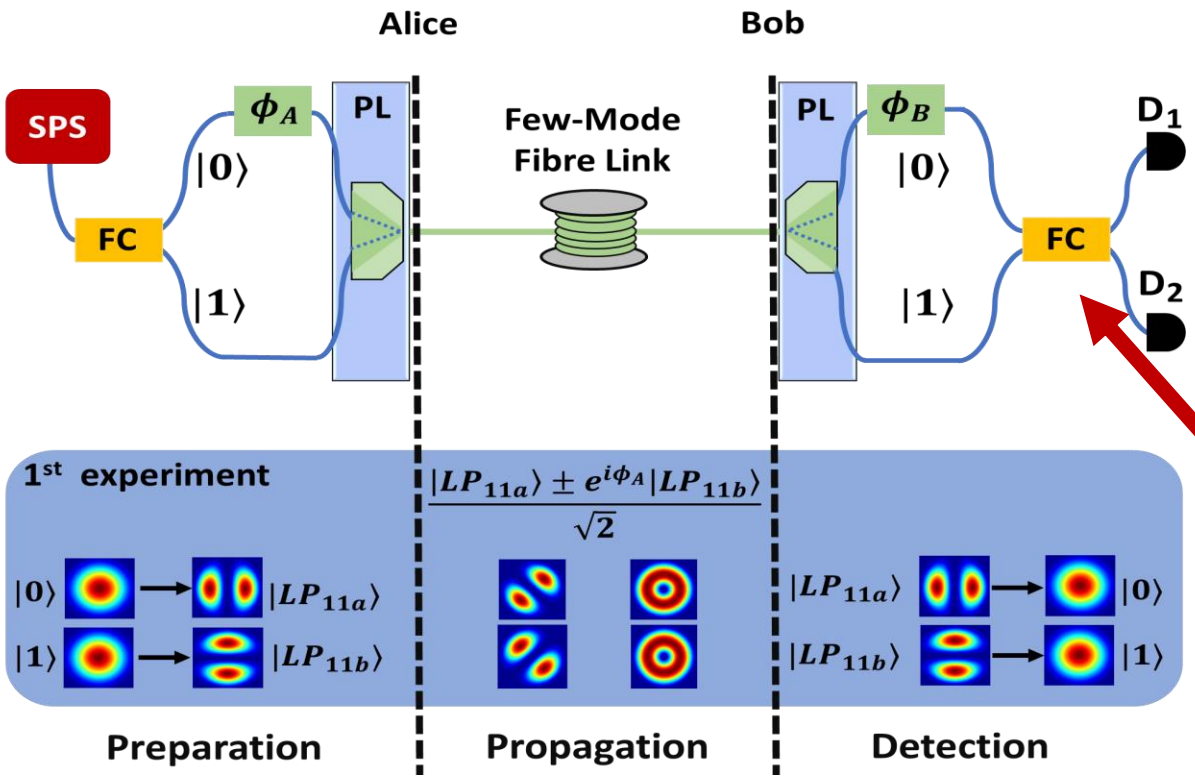


We can also map each LP mode as a basis element of the 2-dimensional state by using 2 ports of the lantern :



Our proposal

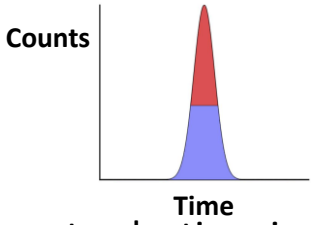
Few-mode-fiber interferometer configuration



Phase encoded qubit

$$|\psi\rangle = \frac{1}{\sqrt{2}}\left(|0\rangle + e^{i\phi_A}|1\rangle\right)$$

Output probabilities proportional to $\boldsymbol{cos^2(\phi_A - \phi_B)}$ and $\boldsymbol{sin^2(\phi_A - \phi_B)}$



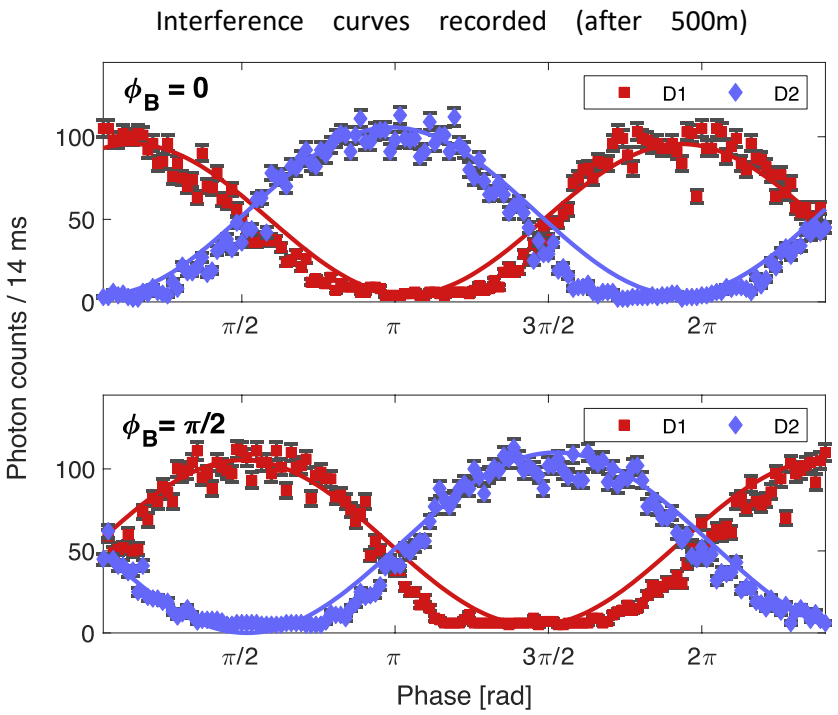
No post-selection is needed since the pulses arrive together, so we can remove intrinsic losses of time-bin

Like the time-bin setup, only one fiber is used.

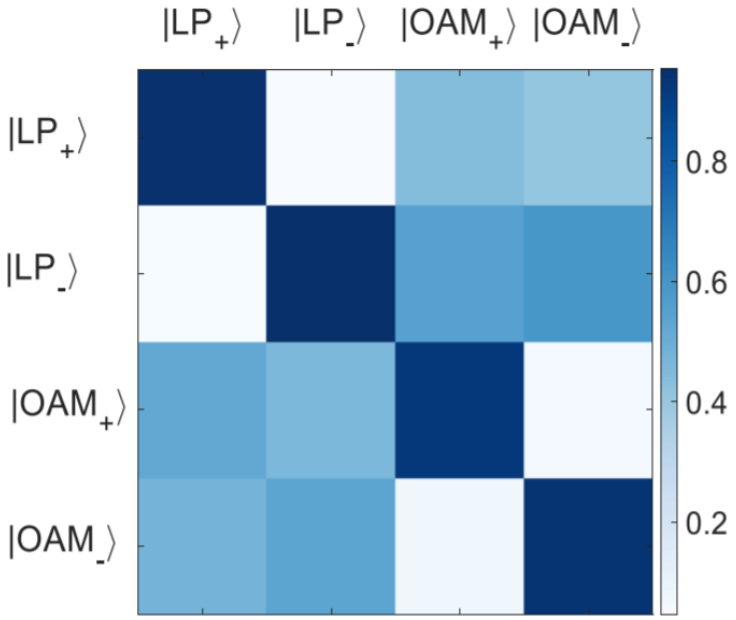
Our proposal

Single-photon regime (weak coherent pulses):

Single-photon interference fringes



500 m

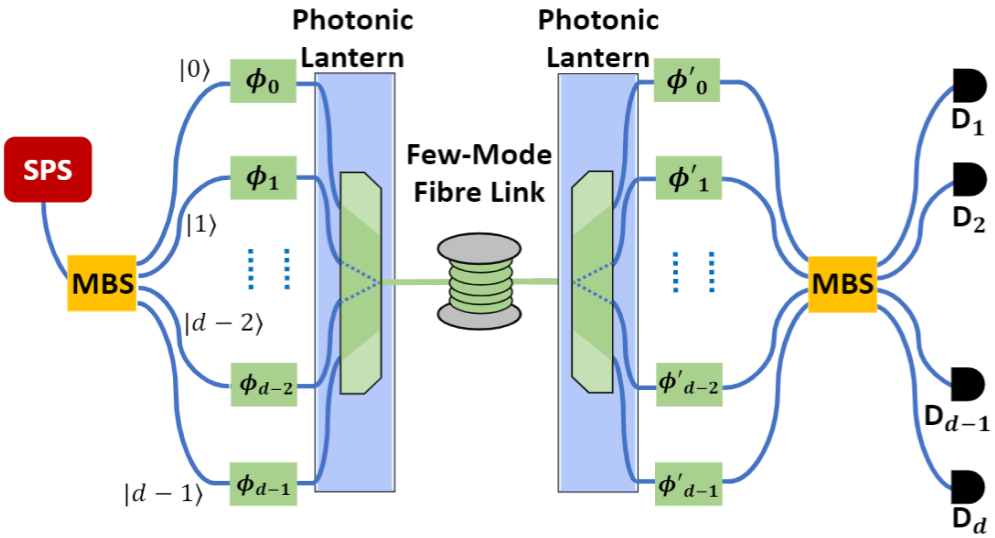


Average probability of main diagonal is 0.951 ± 0.024 for 500 m.

A. Alarcón et al, Phys. Rev. Applied (Accepted) (2021). arXiv:2103.05018

Where to go from here?

- Perform a complete QKD session.
- Increase the transmission distance.
- Expanding the setup to higher dimensions.



$$|\psi\rangle = \frac{1}{\sqrt{d}} \sum_{i=0}^{d-1} \alpha_i |i\rangle$$

A. Alarcón et al, Phys. Rev. Applied (Accepted) (2021). arXiv:2103.05018

Thank you!

- Feel free to contact me for comments/suggestions/questions: alvaro.alarcon@liu.se

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